RESEARCH FACILITIES IN AEOLIAN GEOSCIENCES: AN INVENTORY

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ABSTRACT

The results are presented of an inquiry set up to make an inventory of the technical facilities currently (1995) available in aeolian geosciences. A questionnaire was sent to 358 research units involved in aeolian georesearch. Seventy-two units responded. Although this is only 20 per cent, the major aeolian units did respond. The inquiry consists of five parts. Part one sought general information about the research units. Part two investigated the importance of aeolian research in the total research activity of each unit, and the way the research is carried out. Part three focused on the laboratory equipment, and part four on the field equipment. Part five lists the research topics and major fields of interest.

KEY WORDS wind; aeolian; research facilities; equipment

INTRODUCTION

Aeolian research has long been a minor topic in geoscience. Even today, relatively few researchers are involved in the study of aeolian processes and landforms. Studies of the natural environment, and of the physical and chemical processes that occur in that environment, have long been restricted to countries in humid climates. There, water (and other factors) affect the environment much more than wind.

Before the 1970s aeolian erosion, transport and deposition of soil particles was primarily a field for agricultural engineers. The catastrophic wind erosion that affected the North American Great Plains in the 1930s and 1950s, and the immense dust storms that resulted from that erosion, forced soil scientists to study the process of wind erosion and to look for practical solutions to combat the problem. Much progress was made in this domain in the 1950s and 1960s. People like W. S. Chepil, A. W. Zingg, N. P. Woodruff, and their colleagues, can be considered the founders of modern scientific wind erosion abatement. The true aeolian pioneer, however, was R. A. Bagnold, who published in 1941 his famous book *The Physics of Blown Sand and Desert Dunes*. This was the first book to describe in detail the physical principles of aeolian erosion, transport and deposition of natural particles. Bagnold's concepts were based on new developments made only a few years earlier in aerodynamics, but they were also based on his many observations in the Libyan desert and on detailed experiments conducted in his own wind tunnel. *The Physics of Blown Sand and Desert Dunes* is probably the most frequently cited book in the earth science literature.

From the early 1970s, more people became interested in aeolian processes. The severe drought affecting large parts of Sahelian Africa at that time drew attention. It showed the world that desertification was a major modern environmental problem. In the same period, the technical evolution of the means of transport reached a level that gave many scientists access to vast desert areas. The establishment of numerous new oil production sites in the Middle East and northern Africa also contributed to the accessibility of the deserts. This increased accessibility dramatically changed the political and socioeconomic significance of these areas. Many arid and semi-arid countries no longer consider their desert surfaces a nuisance that obstructs their economic development: they now increasingly appreciate their important potential. Several arid countries

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recently established well-equipped desert institutes to investigate the development, and even the transformation, of desert regions into areas usable by man. Since these institutes have a strong multidisciplinary character, many scientific disciplines confront an important aeolian component in their research.

In its earliest days, aeolian research was conducted with modest technical means. Most measurement were made in the field with very simple instruments. Later on, the first geoscientific wind tunnels were constructed. These allowed researchers to study aeolian processes in the laboratory, i.e. under controlled conditions. Until the end of the 1960s most geoscientific wind tunnels were in the USA. The geographical and disciplinary enlargement of aeolian georesearch later stimulated the construction of aeolian tunnels in many parts of the world. Apart from wind tunnels, there is the analysis of aerial photographs and satellite images, and there is the computer to model aeolian processes. In the field, many institutes now have fully equipped meteorological towers and stations to measure aeolian erosion, transport and deposition. Most institutes also have equipment to analyse the aeolian sediments (mineralogical and chemical composition, grain size distribution, etc.).

Up to the present, no inventory existed of the research facilities currently available in the field of aeolian geoscience. Since such an inventory may be of interest to many investigators, we drew up a questionnaire and sent it out to many research units currently (February 1995) involved in aeolian georesearch. The names and addresses of these units were collected by screening the aeolian literature (books, journal articles, proceedings of conferences and symposia) and participation lists of aeolian meetings. Since several former units are now closed, only the literature from 1985 on was thoroughly screened. Literature older than 1985 was checked in less detail.

Several organizations contacted from meeting participation lists did not respond. In addition, journals with a rather limited geographical distribution could not always be screened in detail for the complete period (1985–1995). This means that several units currently involved in aeolian georesearch may have been overlooked. Units that regularly publish in the international geoscientific literature should have received a questionnaire, however.

In total, 358 formulars were sent out. Seventy-two (or 20 per cent) were returned. Most researchers answered with great care, but others remained rather vague and gave only general answers to specific questions. Sometimes these answers were sufficiently clear (e.g. *Question*: How do you determine the particle size distribution of your sediments? Give Method(s) and instruments(s). *Answer*: Sieves.), but in other cases the answer could not be used (e.g. *Question*: How do you measure the airborne sediment concentration? Specify method + instrument. *Answer*: Various systems.). This required response classes of the type 'not specified' or 'unspecified methods' when the results of the inquiry were tabulated.

Several aspects of aeolian research were investigated. Part one of the inquiry requested general information about the research unit, such as the name and address of the unit and the person to be contacted. Part two examined the importance of aeolian research in the total research activity of each unit, and also investigated the way this research is carried out. Part three focused on the laboratory equipment, and part four on the field equipment. In part five, finally, the units were asked to indicate their research topics and field of interest.

The results of the inquiry are presented below. To facilitate cross-referencing in the text, each research unit received an acronym. These acronyms, with the unit's names and addresses, appear in the Appendix on the disk.

RESULTS

General questions

(i) Importance of aeolian research in the total research activity of the units.

Questions

1. Is your research unit, besides being involved in aeolian georesearch, also involved in other georesearch?
2. Does aeolian georesearch form a major or a minor topic in the activities of your research unit?
3. How many researchers (in your unit) are currently involved in aeolian themes, how many of them obtained a Ph.D. degree, and how many are preparing a Ph.D. thesis?

The great majority of the units are active in different geoscience domains. Only 8 per cent are exclusively involved in aeolian research. Aeolian themes remain, however, important topics: 54 per cent of the units consider aeolian research a major research activity.

Aeolian units are usually small. The average number of researchers per unit is three. The largest unit has 13 researchers. In 20 per cent of the units there is only one researcher. About 26 per cent of the researchers are Ph.D. students.

(ii) Type of research

Questions

1. Where does your aeolian research take place: in a laboratory, in the field, or both in the laboratory and in the field?
2. How is your research mainly carried out: theoretically, laboratory experiments, field experiments, computer simulations, image analysis, ... (specify) ... ?

In most units (66 per cent) aeolian research is carried out both in the laboratory and in the field. Nearly 32 per cent of the units work exclusively in the field, and 2 per cent are involved solely in laboratory research.

Most units use more than one research method. About 85 per cent do field research (experiments, measurement, observations), 52 per cent do laboratory research (experiments, sediment analysis), 23 per cent theoretical research, 26 per cent image analysis, and 29 per cent use the computer to model aeolian processes.

Laboratory instruments

(i) Wind tunnels

Question

Does your unit have its own laboratory wind tunnel?

As could be expected, only a minority (38 per cent) of the units has its own wind tunnel. There is usually only one wind tunnel per unit. Several units (AAR, BIG, DAV, LEU, MAN, MOF) have more than one tunnel, or more than one test section per tunnel. Several units also have the use of field wind tunnels. These latter are dealt with in a later section.

Question

Describe the characteristics of the wind tunnel(s) you use.

Sub-questions

1. Is your wind tunnel an open or a closed wind tunnel?
2. If your tunnel is closed, is it a horizontal or a vertical tunnel?
3. How many test sections are there available?
4. Dimensions of the test sections(s): length (including usable fetch), width, height.
5. Is the position of the roof adjustable or fixed?
6. Is the tunnel a suction tunnel or a blowing tunnel?
7. Wind speed range in test section (free-stream velocity).
8. Do you generate boundary layers in your wind tunnel and, if yes, which methods do you use?
9. Does your wind tunnel operate under low-pressure conditions, high-pressure conditions or normal atmospheric pressure conditions?
10. Can you control the vertical temperature gradient in the test section?

Table I (all Tables are on the disk) gives an overview of the characteristics of the wind tunnels reported in the inquiry. Most tunnels are of the open type. The length of the test section (including the usable fetch) varies from 0·5 to 16 m, its width from 0·1 to 1·5 m, and its height from 0·1 to 3·5 m. In 32 per cent of the tunnels the position of the roof is adjustable.

Most of the tunnels (62 per cent) are suction tunnels, i.e.there is a small underpressure in the test section while the tunnel is operating. Maximum free-stream wind velocity is generally around 20 m s^{-1}, although higher wind speeds can be generated in several tunnels. Highest wind speed (120 m s^{-1}) is generated in the MOF1 tunnel, but this is a low-pressure tunnel built to study aeolian processes on Mars.

Boundary layers are generated in 84 per cent of the tunnels. A wide variety of techniques is used for this purpose. The vertical temperature gradient, on the other hand, is usually not adjustable, except in the DEB and MOF1 tunnels. Most tunnels are, therefore, neutral-flow wind tunnels.

Special tunnels are the low-pressure MOF1 tunnel, in which aeolian processes on Mars are simulated, the high-pressure MOF2 tunnel, in which aeolian processes on Venus are simulated, and the AAR2 tunnel, which is an inclined wind tunnel whose test section angle is adjustable between −25° and +25°.

Questions

1. How do you measure the wind speed in your wind tunnel: screw or cup anemometer, pitot tube, hot-wire anemometer, velocimeter, other methods (specify)?
2. Can you measure wind directions in your wind tunnel and, if yes, with which instrument(s)?
3. Can you measure turbulence in your wind tunnel and, if yes, with which instrument(s)?

In the geoscientific wind tunnels reported in the inquiry, wind speed is usually measured by means of pitot tubes (92 per cent of the units) and/or hot-wire anemometers (65 per cent of the units). Other instruments, such as screw anemometers, cup anemometers and velocimeters, are less frequently used. Wind direction is measured in a few tunnels only. In most tunnels it is assumed that the airflow is parallel to the tunnel walls. The assumption is not always justified, however, and a good wind tunnel calibration programme should always include flow direction measurements. Turbulence, finally, is measured in 54 per cent of the tunnels. It is usually measured by means of hot-wire anemometers.

Question

Can you visualize the airflow in your wind tunnel? If yes, which method(s) and instrument(s) do you use?

Airflow can be visualized in 46 per cent of the tunnels. The great majority use smoke.

Questions

1. Do you add particles to the airflow during your wind tunnel experiments, or do you only work with clean, unladen air?
2. If you add particles:
   a. Which type of particles do you use: sand, dust, snow, soil, other particles (specify)?
   b. Grain size of the particles.
   c. How do you feed the air in the wind tunnel with particles: funnels, rotating table, dosage balance, high-pressure injectors, other methods (specify)?
   d. How do you measure sediment concentration (describe method(s) and instrument(s))?

As could be expected, sediment is added to the airflow in most of the geoscience wind tunnels. Sand (78 per cent) and soil (38 per cent) are the sediments most frequently used. In the case of loamy soils, some of the grains consist of fine silt and clay. These particles are transported as aeolian dust. There are two wind tunnels (LEU1 and LEU2) that exclusively deal with aeolian dust. Other particles, such as snow, glass beads or walnut shells, are only rarely used.

Funnels are the most common instruments used to feed the airflow with particles. Another popular technique is to erode sediment-covered surfaces located upstream of the test section. Other instruments (or techniques), such as the dosage balance, are less frequently used in geoscientific tunnels.

Direct measurements of the airborne sediment concentration are made in a few tunnels only. In several other tunnels, concentration is measured indirectly, via determination of the amount of sediment transport.

Questions

1. Do you use important wind tunnel equipment that has not been mentioned earlier in this questionnaire? If yes, specify (instrument + purpose).
2. Do you plan to extend your wind tunnel equipment in the near future? If yes, specify.

Additional wind tunnel equipment that was mentioned included: a Beckman hydrocarbon flame analyser (DAV), Scanivalve pressure measurement systems (DAV), a hanging surface to measure drag forces (MUN), low volume PM10 samplers (PUL), mass balance trays (MAN), a laser instrument to determine the initiation of particle movement (GUE, LEU), a laser velocimeter (AME), a controlled energy dust

generator (LUB), a shear stress plate (GUE), and a turbulence lattice for various turbulence flow scales (TSU).

Most research units do not plan to extend their wind tunnel equipment in the near future. The following extensions were mentioned: a force balance system (DAV), instruments to measure the soil surface water content by infrared reflexion (MUN), removable wind tunnel floors that simulate different surface conditions (PUL), a three-dimensional (3D) coordinate framework in the wind tunnel (LAN), an automatic sand feeder (LAN), isokinetic dust samplers to determine airborne dust concentration (LEU), visualization equipment (Schlieren system, high-speed camera) (CAI), wind tunnel rainfall simulators (GEN), a laser anemometer (TSU), and instrumentation to measure temperature and humidity profiles (TSU).

(ii) Image analysis

Questions

1. Do you work with aerial photographs and/or satellite images?
2. If yes:
   a. How frequently: frequently, now and then, or only rarely?
   b. Do you have special instrumentation to analyse the pictures?

Nearly 79 per cent of the units that returned the questionnaire use aerial photographs and/or satellite images during their research activities: 43 per cent frequently, 35 per cent now and then, and 22 per cent rarely. The majority of these units use both aerial photographs and satellite images. Several units mention special instrumentation to analyse the pictures. There is great variation in this instrumentation, however, and the information given by the individual units is not always clear. Units that mentioned special image analysis equipment are marked by a Y in the fourth column of Table II.

(iii) Particle size distribution

Question

How do you determine the particle size distribution of your sediments (give method(s) and instrument(s))?

A wide variety of techniques and instruments was mentioned. The fifth column of Table II summarizes the answers to this question. Grain size distribution of coarse particles (sand) is usually determined by means of sieves; for fine particles (silt and clay) various techniques are in use.

(iv) Other laboratory equipment

Question

Is there any other laboratory equipment you want to mention? If yes, give purpose, type of instrument(s) and working principle (if necessary).

A lot of equipment was mentioned. We only summarize the equipment directly related to aeolian research: a 3D transversing probe support system (for wind tunnel) (DAV), a resuspension chamber for quantification of PM10 emissions (PUL, REN), a laser scanning device to determine the roughness and the thickness of sediment layers generated during wind tunnel experiments (GUE, LEU), sand groups (AAR), a wind eroding mass field instrument (ALE), saltiphones (GEN), and an ESR for determination of aeolian dust (HYO).

Field instrumentation

(i) Availability of aeolian field stations

Question

Does your research unit have the use of aeolian field stations? If yes, how many stations do you have?

Forty-four per cent of the research units that returned the questionnaire have at least one aeolian field station. Most units (35 per cent) have only one station; the maximum number of stations per unit is 10. Fourteen per cent of the units do not have an aeolian field station but use stations of other research groups.

(ii) Portable field wind tunnels

Question

Does your unit have the use of a portable field wind tunnel?

Sub questions

1. Is your field wind tunnel an open or a closed wind tunnel?

2. How many test sections are there available?
3. Dimension of the test section(s): length (including usable fetch), width, height.
4. Is the tunnel a suction tunnel or a blowing tunnel?
5. Wind speed range in test section (free-stream velocity).

Field wind tunnels are less numerous than laboratory wind tunnels: only 19 per cent of the research units that returned the questionnaire have their own field tunnel. Table III summarizes the characteristics of these tunnels. Nearly all are open tunnels. They usually have only one test section, although the POZ and RNO tunnels have two, and the LON tunnel has four test sections. The largest tunnel mentioned is the LAN tunnel: 24 m long, 1·2 m wide and 1·2 m high. Most field tunnels (75 per cent) are blowing tunnels.

(iii) Meteorological stations and towers

Questions

1. Do you have the use of instrumented towers? If yes, are they fixed or transportable, how many towers do you have of each type, and what is their height?
2. With which instrument(s) do you measure wind velocity?
3. Is your experimental station/tower equipped with a meteorological station? If yes, which meteorological parameters do you measure?

Forty-eight per cent of the units involved in aeolian fieldwork have at least one instrumented tower at their disposal. Units owning towers usually have more than one tower. Table IV gives an overview. More than 75 per cent of the towers are transportable.

The tallest towers are the 300 m TSU tower, where only meteorological measurements are executed, and the 90 m SDB tower, to which several aeolian dust collectors are attached.

Many field stations (or towers) are equipped with a meteorological station. Table IV summarizes the meteorological parameters that are measured at each field station.

(iv) Aeolian sediment measurements

Questions

1. Do you have sediment collectors at your disposal? If yes:
   a. For which type of sediment?
   b. Which type(s) of collector(s) do you use?
2. Do you measure airborne sediment concentration? If yes:
   a. Which type of sediment do you sample?
   b. How do you measure the concentration? Specify method and instrument.

Aeolian sediment is collected at 71 per cent of the aeolian field sites. The most collected sediment is sand (80 per cent of the units), followed by dust (55 per cent of the units) and soil (39 per cent of the units). Three units also collect snow. As could be expected, many different collector types are in use. Table IV gives an overview.

Airborne sediment concentration is measured by only a minority of research units. One should bear in mind that several of these units measure sediment concentration only indirectly, via calculations based upon the amount of sediment deposition recorded in non-isokinetic ground-level collectors. It is also remarkable that many units do not accurately describe their measurement technique. Care should thus be taken with respect to the data related to airborne sediment concentration.

(v) Airflow visualization

Question

Do you have instruments to visualize the airflow? If yes, describe method(s) and instrumentation.

Four units visualize the airflow in the field: AAR, BEE, BIG and TEM. They use smoke.

(vi) Other field equipment

Question

Is there any other field equipment you want to mention? If yes, give purpose, type of instrument(s) and working principle.

Much additional equipment was mentioned. We summarize only the equipment directly related to aeolian research: erosion pins (ADA, LEU), sensitive particle detectors to detect the onset of deflation and to record

the kinetic energy of impacting grains (PUL), portable field cup anemometers (LEU), a radio-controlled model airplane (SDB), a portable high-volume dust sampler (SDB), a portable laser-doppler anemometer (AAR), portable hot-wire anemometers (AAR), electron spin resonance equipment for determination of the origin and age of aeolian dust (HYO), and tethered balloons for meteorological studies (BAT).

(vii) Environments studied

Question

In which natural environment(s) do you carry out your field measurements?

Table IV summarizes the results. The most frequently mentioned environments are: dune areas (25 units), deserts (17 units), agricultural fields (14 units) and sand beaches (12 units). Several additional environments were mentioned, but these seem to be of less interest to most research units.

Research interests

Question

Can you list some key-words to indicate your field(s) of interest.

Table V gives an overview of the answers to this question. We hope that this information may lead to new cooperative projects between aeolian research units.

CONCLUSIONS

The majority of the aeolian research units, even the small ones, seem to be well equipped. Many aeolian units are connected to a larger laboratory (or research institute) and thus enjoy the use of important standard equipment shared between different groups.

Most aeolian units conduct their research in both laboratory and field.

Laboratory activities principally include wind tunnel work, the simulation of aeolian processes on computers, image analysis (aerial photographs, satellite images), and analysis of the physical and chemical properties of aeolian sediments. Several research units have at least one well-equipped wind tunnel at their disposal. In many of these tunnels, sediment can be supplied to the airflow, thus making the simulation of particle transport and deposition possible under controlled conditions. Other units have powerful computers with which aeolian sediment dynamics, especially sand dynamics, can be simulated. Almost every unit has at least one instrument to determine the grain size distribution of aeolian sediments. Several units have specific equipment (both hardware and software) to analyse aerial photographs and/or satellite images.

Fieldwork is conducted in many environments. Most of the units involved in aeolian fieldwork have one or more experimental field stations available. Several units have portable field wind tunnels. Many units also have instrumented towers, which are either fixed or transportable. Several of these towers penetrate deeply into the atmospheric boundary layer. Many towers are equipped with meteorological stations.

Aeolian-transported sediment is collected in many field stations. A wide variety of collectors are in use. Airborne sediment concentration, on the other hand, is less frequently measured.

We realize that the results presented in this paper are incomplete. Several research units did not respond to the questionnaire and others may have been overlooked. We nevertheless hope that the inventory may be of interest to aeolian georesearchers, and that it may result in a still more intense cooperation between research units.